CAPACITY CONTROL VALVE FOR VARIABLE DISPLACEMENT COMPRESSOR

BACKGROUND OF THE INVENTION

(1) Field of the Invention

This invention relates to a capacity control valve for a variable displacement compressor, and more particularly to a capacity control valve for a variable displacement compressor disposed in a refrigeration cycle of an automotive air conditioning system, for compressing a refrigerant gas.

(2) Description of the Related Art

In an automotive air conditioning system, a variable displacement compressor capable of changing the capacity of refrigerant is employed so as to obtain adequate cooling capacity without being restricted by rotational speed of an engine. In the above-mentioned variable displacement compressor, pistons for compressing refrigerant are connected to a wobble plate fitted on a rotating shaft driven by the engine, and the angle of the wobble plate is varied to change the length of piston stroke, whereby the delivery quantity of the compressor is changed. The angle of the wobble plate is continuously changed by introducing part of the compressed refrigerant into a gastight crank chamber and changing pressure within the crank chamber, and thereby changing a balance between pressures applied to the respective both end faces of each

piston.

Now, the amount of compressed refrigerant to be introduced into the crank chamber is controlled using a capacity control valve. The capacity control valve is disposed, for example, in an intermediate portion of a refrigerant flow path extending from a discharge chamber to the crank chamber within the compressor, and controls the amount of refrigerant to be introduced, such that the differential pressure between pressure within the discharge chamber and pressure within a suction chamber is held at a predetermined value. The value of the differential pressure to be controlled can be externally set by the value of electric current applied to a solenoid.

By this control operation of the capacity control valve, pressure to be introduced into the crank chamber is increased when the rotational speed of the engine increases, so as to reduce the volume of refrigerant which can be compressed, and reduced when the rotational speed of the engine decreases, so as to increase the volume of refrigerant which can be compressed. Thus, the amount of refrigerant discharged from the compressor is held at a predetermined amount without being influenced by variations in the rotational speed of the engine.

In this type of variable displacement compressor, lubricating oil is mixed into refrigerant to thereby maintain lubrication of the inside of the compressor. Further, for example, a compressor is known in which a

passage extending from a discharge chamber to a crank chamber via a capacity control valve within the compressor is used as an oil return passage, so as to efficiently introduce lubricating oil contained in refrigerant into the compressor.

Another compressor employs an oil separator so as to return lubricating oil in refrigerant into a crank chamber efficiently. The oil separator is often disposed in a passage, such as the above-mentioned oil return passage, for returning refrigerant discharged from a discharge chamber to a crank chamber without causing the refrigerant to flow through an external refrigerant circuit. On the other hand, still another compressor has been proposed which has an oil separator disposed in an extraction passage communicating between a crank chamber and a suction chamber, such that separated lubricating oil is introduced into a passage extending from a capacity control valve to the crank chamber, whereby a time period required for returning lubricating oil discharged from the discharge chamber to the crank chamber is shortened (see e.g. Japanese Unexamined Patent Publication No. 2002-213350, (paragraph numbers [0062] to [0066], FIG. 1) for example).

In one of the above conventional variable displacement compressor, in which the passage extending from the discharge chamber to the crank chamber via the capacity control valve within the compressor is used as

the oil return passage, it is possible to return lubricating oil contained in refrigerant to the crank chamber by a simple construction. However, the amount of lubricating oil to be returned from the discharge chamber to the crank chamber is much influenced by the adjusted state of the valve lift of the capacity control valve. For example, when the capacity control valve is fully closed, return of lubricating oil to the crank chamber is cut off, and hence lubrication of the inside of the compressor cannot be maintained, which, in the worst case, can cause seizure of pistons to stop the operation of the compressor. On the other hand, when the oil separator is used, the construction of the compressor is made complicated, and the size of the whole compressor is increased by the provision of the oil separator.

SUMMARY OF THE INVENTION

The present invention has been made in view of the above problems, and an object thereof is to provide a capacity control valve for a variable displacement compressor, which is capable of efficiently returning lubricating oil contained in refrigerant to a crank chamber of the compressor, by a simple construction.

To solve the above problem, the present invention provides a capacity control valve for a variable displacement compressor, for controlling an amount of refrigerant introduced from a discharge chamber into a

crank chamber, to thereby change a capacity of refrigerant discharged from the variable displacement compressor, characterized in that a communication passage is formed in a valve seat-forming member disposed in a refrigerant passage communicating between the discharge chamber and the crank chamber for constantly communicating between a discharge chamber side and a crank chamber side.

According to the capacity control valve for a variable displacement compressor, constructed as above, since the communication passage through which the discharge chamber and the crank chamber communicate with each other is additionally formed in the valve seat-forming member disposed between the discharge chamber side and the crank chamber side within the variable displacement compressor Therefore, even when a valve element is seated on a valve seat for closing the capacity control valve, refrigerant is introduced into the crank chamber, whereby lubricating oil is returned.

The above and other objects, features and advantages of the present invention will become apparent from the following description when taken in conjunction with the accompany drawings which illustrate preferred embodiments of the present invention by way of example.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a central longitudinal cross-sectional view showing the construction of a capacity control valve

according to a first embodiment of the present invention;

FIG. 2 is an enlarged view of a valve element and its neighborhood of the capacity control valve shown in FIG. 1;

FIG. 3 is a central longitudinal cross-sectional view showing the construction of a capacity control valve according to a second embodiment of the present invention;

FIG. 4 is an enlarged view of a valve element and its neighborhood of the capacity control valve shown in FIG. 3;

FIG. 5 is a central longitudinal cross-sectional view showing the construction of a capacity control valve according to a third embodiment of the present invention; and

FIG. 6 is an enlarged view of a valve element and its neighborhood of the capacity control valve shown in FIG. 5.

DESCRIPTION OF THE PREFFERED EMBODIMENTS

Hereinafter, embodiments of the present invention will be described in detail with reference to the drawings.

FIG. 1 is a central longitudinal cross-sectional view showing the construction of a capacity control valve according to a first embodiment of the invention.

The capacity control valve 100 shown in FIG. 1 is arranged in an intermediate portion of a refrigerant flow path extending from a discharge chamber to a crank chamber

within a variable displacement compressor e.g. for an automotive air conditioning system, and used for controlling the capacity of refrigerant introduced into the crank chamber to thereby change the amount of refrigerant to be discharged from the variable displacement compressor.

The capacity control valve 100 includes a spherical valve element 2 disposed in the refrigerant flow path formed in an upper body 1, which communicates at one end with the discharge chamber and at the other end with the crank chamber. The upper body 1 has an inner space communicating with the crank chamber, and has a valve seat-forming member 3 press-fitted in an upper opening thereof. Further, a strainer 4 is mounted on the upper body 1 in a manner covering the upper edge thereof. The strainer 4 has an inner space communicating with the discharge chamber. A valve hole 5 communicating between the discharge chamber-side space and the crank chamber-side space is formed in a valve seat-forming member 3. The crank chamber-side end of the valve hole 5 functions as a valve seat, and the valve element 2 is disposed in a manner opposed to the valve hole 5. Further, a through hole 6 extending in parallel with the valve hole 5 is formed in the valve seat-forming member 3 for communicating between the discharge chamber-side space and the crank chamber-side space.

The upper body 1 is press-fitted in the upper

opening of a lower body 7. A piston rod 8 having the same diameter as that of the valve hole 5 (to be more precise, a portion corresponding to the valve seat on which the valve element 2 is seated) of the valve seat-forming member 3 is disposed along the axis of the upper body 1 in a manner capable of axial reciprocating motion. The piston rod 8 has one end thereof in abutment with the valve element 2 on a side of the valve element 2 remote from the valve hole 5, and the other end thereof exposed in the inner space of the lower body 7. The inner space of the lower body 7 communicates with a suction chamber of the variable displacement compressor, and hence the piston rod 8 receives suction pressure Ps from the suction chamber at the end thereof exposed in the inner space of the lower body 7. It should be noted that the lower body 7 has a lower opening thereof closed by a cap 9.

Within the lower body 7, there are arranged a fixed core 10 and a sleeve 11 of a solenoid section. The fixed core 10 has an upper central opening screwed into the lower portion of the upper body 1. Further, a shaft 12 is inserted along the axis of the fixed core 10 in a manner capable of axial reciprocating motion. The shaft 12 has one end thereof in abutment with the end of the piston rod 8, and the other end thereof fitted in a movable core 13. Thus, the shaft 12 and the movable core 13 can axially slide in unison. Further, the sleeve 11 is surrounded by a solenoid coil including a bobbin 14 and a magnet wire 15.

It should be noted that a spring 16 is disposed between the movable core 13 and the fixed core 10, while a spring 17 is disposed between the end of the movable core 13 remote from the fixed core 10 and the bottom of the sleeve 11.

An O ring 18 is provided around the periphery of the upper body 1 for sealing between the portion communicating with the discharge chamber and receiving discharge pressure Pd and the portion communicating with the crank chamber and receiving pressure Pc from the same when the capacity control valve 100 is mounted in the variable displacement compressor. On the other hand, an O ring 19 is provided around the periphery of the lower body 7 for sealing between the portion receiving the pressure Pc from the crank chamber and the portion communicating with the suction chamber and receiving the suction pressure Ps, and an O ring 20 is provided around the periphery of the lower body 7 for sealing between the portion receiving the suction pressure Ps and an atmosphere.

Referring next to FIG. 2, there is shown the valve element 2 and its neighborhood of the capacity control valve 100 shown in FIG. 1, on an enlarged scale.

As described hereinabove, the valve seat-forming member 3 is fitted in the upper opening of the upper body 1, and the strainer 4 is mounted on the upper edge of the upper body 1. The inner space of the strainer 4 communicates with the discharge chamber of the variable

displacement compressor, while the inner space of the upper body 1 communicates with the crank chamber of the same. The valve seat-forming member 3 is so formed as to have the valve hole 5 and the through hole 6 extending in parallel with the valve hole 5, both of which communicate between the discharge chamber-side space and the crank chamber-side space.

Further, the valve hole 5 has the crank chamber-side end thereof functioning as the valve seat 5a on which the valve element 2 is seated. The valve element 2 is held by a valve element-holding member 21. The valve element-holding member 21 is disposed in the lower opening of the valve seat-forming member 3 in a manner slidable along the axis of the piston rod 8, for causing the valve element 2 to open and close the valve hole 5. Between the valve-holding member 21 and the bottom portion of the valve seat-forming member 3, which is opposed to the valve element-holding member 21 from a valve element side, there is disposed a spring 22 for urging the valve element element-holding member 21 in a direction that the valve element 2 gives openness.

Now, the operation of the capacity control valve 100 will be described together with the operation of the variable displacement compressor.

Within the capacity control valve 100, the discharge pressure Pd of refrigerant introduced from the discharge chamber acts leftward, as viewed in the figure, on the

valve element 2. On the other hand, the suction pressure Ps from the suction chamber acts rightward, as viewed in the figure, on the piston rod 8 in contact with the valve element 2. The piston rod 8 has the same diameter as that of the valve hole 5, and hence an effective pressure-receiving area of the valve element 2 on which the discharge pressure Pd is received is equal to a pressure-receiving area of the piston rod 8 on which the suction passage Ps is received. Therefore, the valve element 2 controlling the flow rate of refrigerant from the discharge chamber to the crank chamber forms a differential pressure valve that senses a differential pressure between the discharge pressure Pd and the suction pressure Ps and operates in response thereto.

In the capacity control valve 100, when no control current is supplied to the magnet wire 15 of the solenoid section, the discharge pressure Pd pushes the valve element 2 open, and hence the capacity control valve 100 is fully opened. As a result, in the variable displacement compressor, the value of the pressure Pc in the crank chamber is held close to the discharge pressure Pd, and hence the difference between pressures applied to the both end faces of each piston provided in a manner facing the crank chamber for compressing refrigerant is minimized. Therefore, a wobble plate provided in the crank chamber, for determining the length of piston stroke is inclined at such an inclination angle that minimizes the length of

piston stroke, thus controlling the variable displacement compressor to a minimum capacity operation.

When a maximum control current is supplied to the magnet wire 15 of the solenoid section, the movable core 13 is attracted by the fixed core 10 and moved rightward, as viewed in the figure, whereby the capacity control valve 100 is fully closed. Consequently, by maintaining communication between the suction chamber side and the crank chamber side via an orifice, refrigerant in the crank chamber is allowed to flow into the suction chamber via the orifice, whereby the pressure Pc within the crank chamber is lowered to a value close to the suction pressure Ps within the suction chamber. As a result, the difference between the pressures applied to the opposite end faces of each piston is maximized, whereby the wobble plate is inclined at such an inclination angle that maximizes the length of piston stroke, thus controlling the variable displacement compressor to a maximum capacity operation.

During execution of normal control in which a predetermined control current is supplied to the magnet wire 15 of the solenoid section, the movable core 13 is attracted toward the fixed core 10 according to the magnitude of the control current, i.e. a force for moving the movable core 13 rightward, as viewed in the figure, is generated. This force serves as a set value for the valve element 2 operating as a differential pressure valve.

Therefore, the capacity control valve 100 senses the differential pressure between the discharge pressure Pd and the suction pressure Ps, and controls the flow rate of refrigerant flowing from the discharge chamber to the crank chamber such that the differential pressure is maintained at a differential pressure corresponding to the value set by the solenoid section.

The refrigerant flowing in the capacity control valve 100 and the variable displacement compressor contains lubricating oil, and lubrication of the inside of the variable displacement compressor is maintained by this lubricating oil. Further, the flow path communicating between the discharge chamber and the crank chamber of the variable displacement compressor via the capacity control valve 100 also functions as an oil return passage for returning the lubricating oil. Thus, compressed refrigerant discharged from the discharge chamber returns to the crank chamber through the short route without passing through an external refrigerant circuit, which enables the lubricating oil to be efficiently internally circulated from the discharge chamber to the crank chamber, and then from the crank chamber to the suction chamber via the orifice.

However, when the valve element 2 of the capacity control valve 100 is closed by energization of the solenoid section, flow of refrigerant from the discharge chamber to the crank chamber is stopped, which disables

the function of the flow path as the oil return passage. To overcome this problem, according to the present invention, the communication passage which allows refrigerant to flow to the crank chamber when the capacity control valve 100 is closed is formed in the valve seat-forming member 3 in which the valve hole 5 and the valve seat 5a are formed, to thereby maintain oil circulation.

In the first embodiment shown in FIGS. 1 and 2, the valve seat-forming member 3 has the through hole 6 formed therethrough as this communication passage. As shown in FIG. 2, the through hole 6 extends in parallel with the valve hole 5 in the valve seat-forming member 3, for communicating between the discharge chamber-side space and the crank chamber-side space. The through hole 6 is e.g. circular in cross section, and its cross-sectional area is smaller than that of the valve hole 5. When the valve hole 5 has a diameter of e.g. approximately 1.0 mm to 1.2 mm, it is desirable that the through hole 6 has a circular shape in cross section with a diameter of approximately 0.1 mm to 0.3 mm, with a view to reducing influence on the compression performance of the variable displacement compressor, ensuring flow of lubricating oil from the discharge chamber side to the crank chamber side, facilitating machining, and easily maintaining required accuracy.

Since the through hole 6 configured as above is formed, even when the capacity control valve 100 is closed,

it is possible to secure a refrigerant flow path from the discharge chamber side to the crank chamber side so as to return lubricating oil into the variable displacement compressor. Thus, occurrence of a breakdown of the variable displacement compressor e.g. due to seizure of a piston caused by shortage of lubricating oil within the variable displacement compressor is prevented.

Further, the construction described above causes refrigerant to flow through the flow path extending via the capacity control valve 100, enabling lubricating oil to be returned efficiently, and hence can be suitably employed particularly when a CO_2 refrigerant difficult to mix with lubricating oil is used. Further, circulation of lubricating oil can be easily ensured not by using a complicated device, such as an oil separator, but simply by forming the hole through the valve seat-forming member 3, which contributes to realization of a capacity control valve 100 with a small size and a low failure rate, at low manufacturing costs.

FIG. 3 is a central longitudinal cross-sectional view showing the construction of a capacity control valve according to a second embodiment of the present invention, and FIG. 4 is an enlarged view showing a valve element and its neighborhood of the capacity control valve shown in FIG. 3. It should be noted that component parts in FIGS. 3 and 4 which are identical to those of the capacity control valve in FIGS. 1 and 2 are designated by identical

numerals, and detailed description thereof will be omitted.

The capacity control valve 200 shown in FIGS. 3 and 4 is distinguished from the first embodiment by the shape of a communication passage formed in a valve seat-forming member 23 disposed between the inner space of the strainer 4 communicating with the discharge chamber and the inner space of the upper body 1 communicating with the crank chamber. The valve seat-forming member 23 has a valve hole 25 for communicating between the discharge chamber-side space and the crank chamber-side space, and has a crank chamber-side end of the valve hole 25 functions as a valve seat 25a on which the valve element 2 is seated. Further, the valve seat 25a has a nick 25b formed on one portion of the peripheral edge thereof.

FIG. 4 shows the capacity control valve 200 in a state in which the valve element 2 is seated. In this state, the valve element 2 is held in contact with the valve seat 25a but not in contact with the nick 25b, and hence a gap is created for allowing refrigerant to flow toward the crank chamber side. This makes it possible to return lubricating oil into the crank chamber even when the valve element 2 is seated.

It is desirable that the nick 25b is formed to have a size small enough to minimize influence on the compression performance of the variable displacement compressor and allow required machining accuracy to be easily achieved, similarly to the communication passage in

the first embodiment. More specifically, when the valve hole 25 has a diameter of approximately 1.0 mm to 1.2 mm, it is desirable to form a nick having an equivalent to the opening area corresponding to that having a diameter of approximately 0.1 mm to 0.3 mm, described in the first embodiment.

Next, FIG. 5 is a central longitudinal cross-sectional view showing the construction of a capacity control valve according to a third embodiment of the present invention, and FIG. 6 is an enlarged view showing a valve element and its neighborhood of the capacity control valve shown in FIG. 5. It should be noted that component parts in FIGS. 5 and 6 which are identical to those of the capacity control valve in FIGS. 1 and 2 are designated by identical numerals, and detailed description thereof will be omitted.

The capacity control valve 300 shown in FIGS. 5 and 6 is distinguished from the first and second embodiments by the shape of a communication passage formed in a valve seat-forming member 33 disposed between the discharge chamber-side space and the crank chamber-side space.

The valve seat-forming member 33 has a valve hole 35 communicating between the discharge chamber-side space and the crank chamber-side space, and a crank chamber-side end of the valve hole 35 functions as a valve seat 35a on which the valve element 2 is seated. The valve seat-forming member 33 is press-fitted in the upper opening of

the upper body 1. More specifically, the inner wall of the upper opening of the upper body 1 and the upper outer peripheral surface of the valve seat-forming member 33 are in contact with each other. In the present embodiment, a communication groove 35b is formed on one portion of the upper outer peripheral surface of the valve seat-forming member 33 such that it extends in an axial direction, whereby the communication passage leading to the crank chamber is secured.

As shown in FIG. 6, the communication groove 35b is formed in a manner extending between the space communicating with the discharge chamber and the space communicating with the crank chamber. Thus, when the valve element 2 is seated, refrigerant flows from the discharge chamber side to the crank chamber side through the communication groove 35b, whereby lubricating oil is supplied into the variable displacement compressor.

The communication groove 35b is formed to have e.g. a V shape or a curved shape in cross section. Further, it is desirable that the cross-sectional area of a gap created between the communication groove 35b and the inner wall of the upper body 1 is small enough to minimize influence on the compression performance of the variable displacement compressor and allow required machining accuracy to be easily achieved, similarly to the communication passages in the above first and second embodiments.

Further, in the present embodiment, after forming the valve seat-forming member 33, it is possible to form the communication groove 35b on the upper outer peripheral surface of the valve seat-forming member by the same method as is used for forming a scribe line, and hence manufacturing efficiency is higher than in the above first and second embodiments.

As described above, in the capacity control valve for a variable displacement compressor, according to the present invention, it is possible to form the communication passage by forming the through hole in the valve seat-forming member in which the valve hole and the valve seat are formed, the nick on the valve seat, or the groove on the outer peripheral surface of the valve seat-forming member, thereby enabling refrigerant to return into the crank chamber even when the valve element is seated, and maintain lubrication of the inside of the variable displacement compressor by lubricating oil so as to prevent breakdown of the compressor. According to the present invention, it is not required to provide any special device for returning lubricating oil, in the variable displacement compressor, and the above advantageous effects can be obtained simply by changing a portion of the internal construction of the capacity control valve. Therefore, it is possible to apply the present invention to any capacity control valve that has a valve element on a flow channel from a discharge chamber

side to a crank chamber side, thereby reducing the size of the capacity control valve and that of a compressor provided with the capacity control valve, and contributing to reduction of the manufacturing costs of these.

It should be noted that although in each of the above embodiments, the capacity control valve performs control such that the differential pressure between the discharge pressure Pd within the discharge chamber and the suction pressure Ps within the suction chamber is held constant, the present invention can also be applied e.g. to a capacity control valve that performs control such that the suction pressure Ps is held constant. Further, although in the above embodiments, the spherical valve element is employed, the invention can also be applied to a case where a valve element having a shape other than the spherical shape is used.

As described heretofore, according to the capacity control valve for a variable displacement compressor, of the present invention, the valve seat-forming member disposed in the refrigerant passage communicating between the discharge chamber and the crank chamber in the variable displacement compressor is so formed as to have the communication passage also communicating between the discharge chamber and the crank chamber, whereby even when the valve element is seated on a valve seat for closing the capacity control valve, refrigerant is introduced into the crank chamber. This enables lubricating oil contained

in refrigerant to be returned into the crank chamber efficiently by the simple construction to thereby maintain lubrication within the crank chamber, which makes it possible to realize a capacity control valve for a variable displacement compressor, which can be manufactured at low costs and seldom suffers a breakdown.

The foregoing is considered as illustrative only of the principles of the present invention. Further, since numerous modifications and changes will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and applications shown and described, and accordingly, all suitable modifications and equivalents may be regarded as falling within the scope of the invention in the appended claims and their equivalents.